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DIAMOND-DRILLING BLAST HOLES
EASTERN MAGNETITE "MINE B"

BY

McHENRY MOSIER

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DIAMOND DRILLING BLAST HOLES, EASTERN MAGNETITE "MINE B"[1]

By McHenry Moiser[2]

INTRODUCTION

This paper is one of a series recently undertaken by the Mining Branch of the Bureau of Mines to describe current practice in diamond drilling for production at various mines throughout the United States and to discuss the relative merits of this method compared with drilling by percussion rock drills.

The Bureau of Mines and the mining companies that are cooperating with it in this investigation have the objective of developing information on diamond-drilling blast holes for the benefit of all who are interested in the possible improvement of mining operations.

HISTORY OF THE DISTRICT

Production of ore began in 1858. The ore was hauled 2.5 miles to a charcoal furnace. Ten years later, a treatment plant using a direct process for making "steel" (probably wrought iron) was built on the property of "Mine B," which was 20 miles from the rail head. During the following 20 years this plant manufactured 10,000 tons of "steel." Operations were terminated when fire destroyed the entire plant. The district remained idle until 1940, when a magnetometer survey was run and exploration work by diamond drilling was started. In 1941, development began at "Mine B," which was approaching full production of 800 long tons of ore per day in April 1946.

GEOLOGY AND ORE DEPOSIT

Magnetite ore occurs as disseminations in gneisses having a wide range in composition and in highly metamorphosed sediments. The wall rocks, which comprise granite, gneiss, and metamorphic sediments, have been intensely folded and distorted.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Inf. Circ. 7401."

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The ore body has a length of 1,500 feet and a maximum width of 60 feet. The known depth, as indicated by diamond drilling to date, is 600 feet along the dip, which is about 40°.

The ore when blasted breaks in blocks separated by slips and seams carrying mica, hornblende, or talc. These fractures lie in three principal directions:

1. Parallel to the bedding in the metamorphic sediments.
2. Normal to the bedding and parallel to the strike.
3. Normal to the bedding and at an angle of 20° either side of the strike.

These factors present a serious hazard to men working in stopes, owing to frequent falls of ground. This danger has been eliminated by diamond drilling, because the drill operator works in a safe place.

The weight factor of the ore in place is 8 cubic feet per long ton.

MINING METHOD

"Mine B" uses the sublevel, open-stope method of mining, with haulage levels on 150-foot vertical intervals from a vertical shaft.

Stopes measure 60 to 195 feet along the strike of the ore body. They are separated by transverse pillars either 15 or 40 feet wide.

Two systems are employed for breaking ore in the stopes because of the variation in dip of the ore body. In one that is used when the dip is steep, vertical rings are drilled at 4-foot intervals along each sublevel subsequent to the completion of a scraper drift from the top of the haulage drift and the belling of draw holes. (See fig. 1.)

Stopes are started with percussion drills by a modified shrinkage method to enlarge the opening above the belled raises on the 30-foot sublevel only. Inclined raises are run on both footwall and hanging wall in the stope along the pillar. Vertical or inclined diamond-drill holes between these two raises are blasted to form a slot, into which the ore from ring drilling is blasted. Both hanging-wall and footwall drifts are run on each sublevel. Ring drilling proceeds in each of these drifts. The depth of the diamond-drill holes ranges from 10 to 60 feet. Spacing at the bottom of the hole is 5 feet. Skimmer holes from each set-up on both hanging-wall and footwall drifts parallel the walls of the stope. These holes, because of irregularities in the walls, insure breaking all the ore. Bootlegs present no problem, because radial holes from the hanging-wall set-up are drilled within 5 feet of the holes from the corresponding set-up on the footwall.

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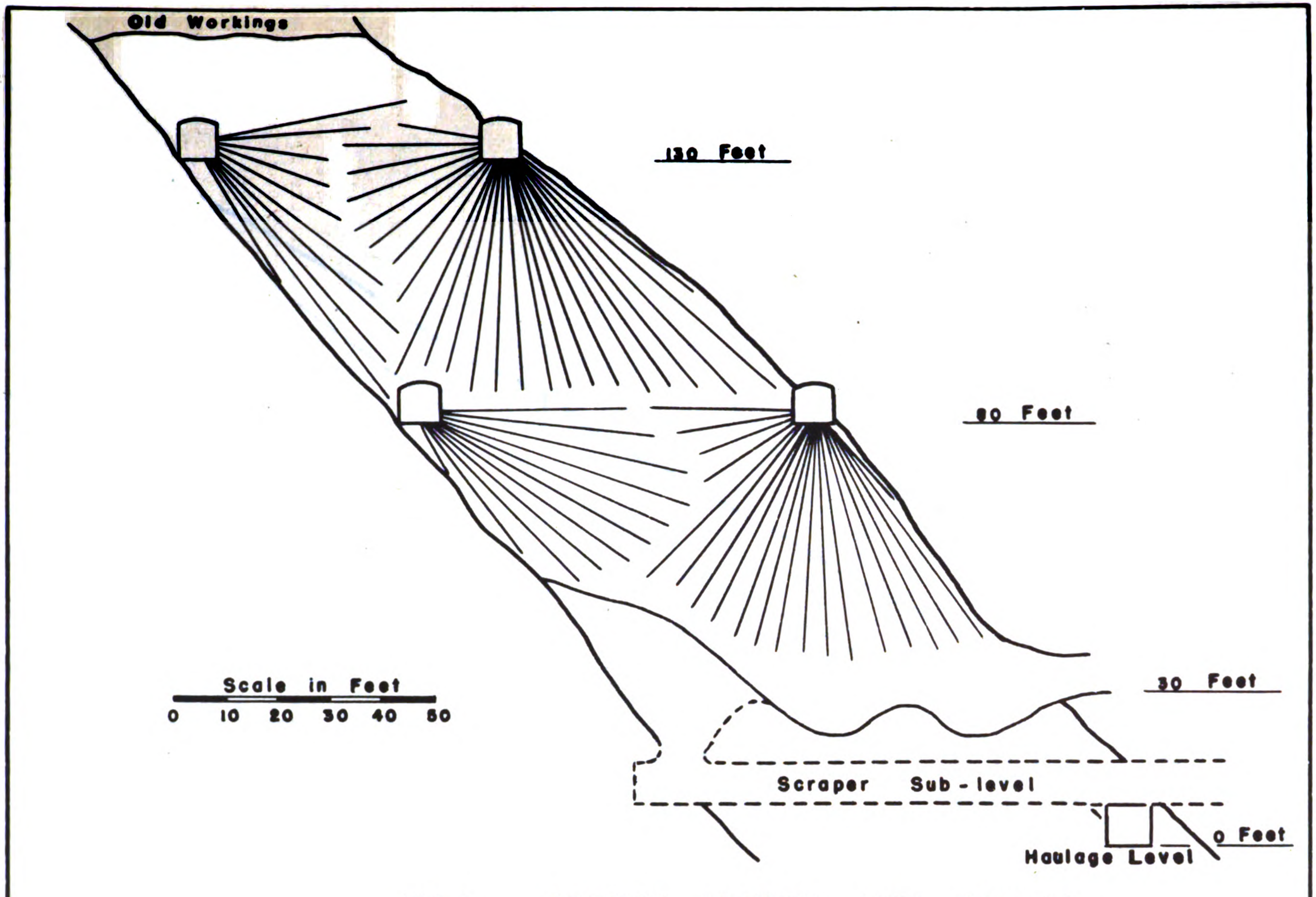

FIG. I SECTION SHOWING RING DRILLING

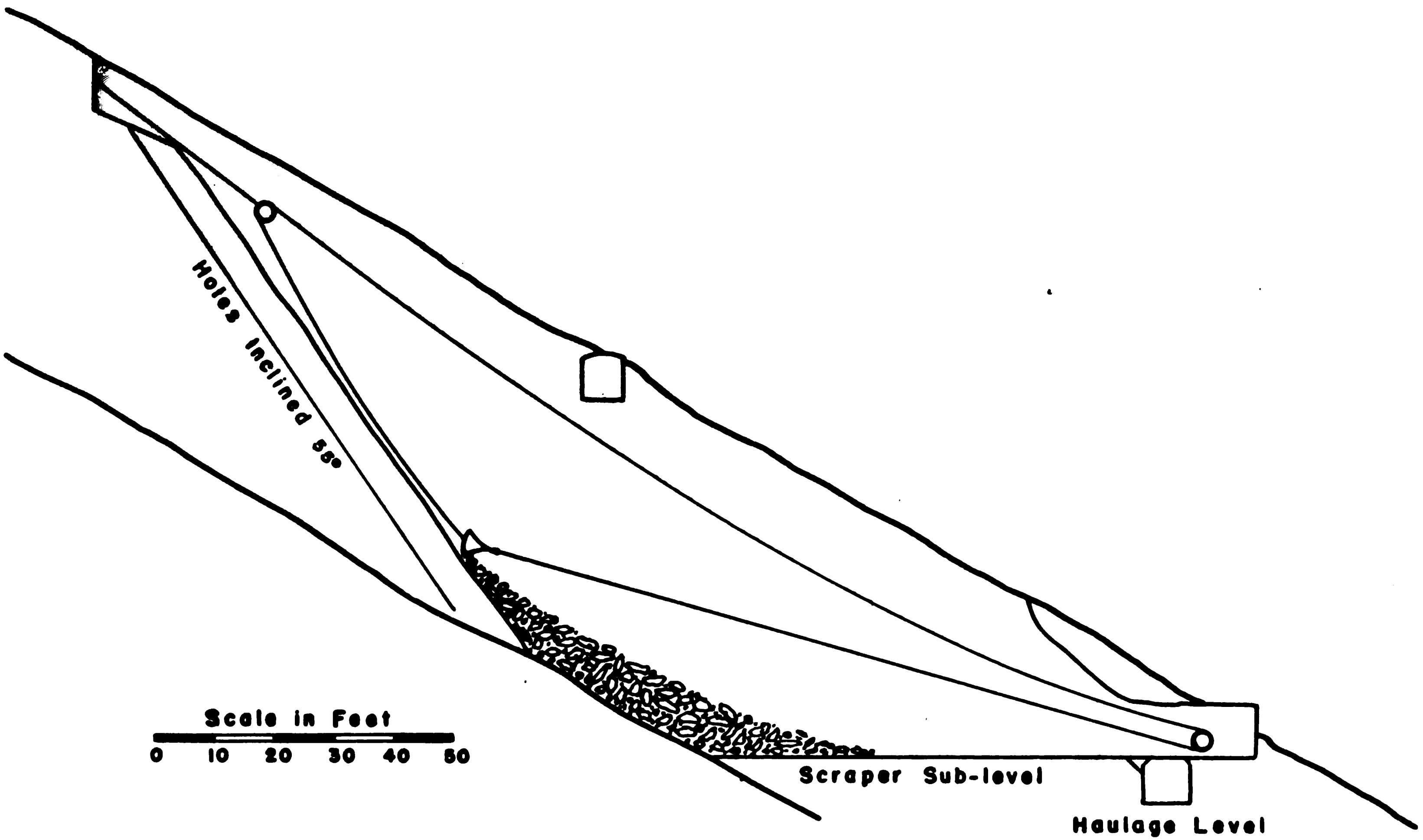

FIG. 2 SECTION SHOWING INCLINED BENCH DRILLING

The other system (the inclined-bench method) is used where the dip is flatter, which in some instances is as low as 26°. The scraper drift is carried nearly horizontal toward the footwall and at the same time is widened to the full width of the slope. In the meantime, a main manway raise along the footwall is driven in the 40-foot pillar between stopes. From this raise, at about 40-foot intervals, short horizontal drifts are driven each way for footwall entrances to the stopes. Also, at these same intervals, raises normal to the dip are driven until they intersect the hanging wall. Short horizontal drifts are then driven from these raises along the hanging wall until they reach the stope line. Simultaneously, a raise from the scraper drift at a point near the haulage drift is driven to the hanging wall and connects to the first manway entrance from pillar raise. Stoping begins by widening this raise with percussion drills to form a slot, after which an inclined bench 10 feet wide is cut with diamond drills. (See fig. 2.) Holes on a 55° angle from the horizontal are drilled in the floor of the bench on 4-foot intervals along a line 4 feet from the breast of the stope. These holes have a maximum depth of 75 feet.

The bench is advanced on a slope parallel to the hanging wall by slashing (slicing or slabbing), keeping about 10 feet ahead of the breast of the stope. The floor of the bench is about 8 feet below the hanging wall. Horizontal blast holes 20 feet in length are used in slashing, which may start at either side of the stope. The burden on these holes is 3 feet. The vertical interval is about 3 feet.

A safety chain is installed along the wall of the bench by attaching it to eye bolts set at waist height on 15-foot intervals. The miners' safety belts are attached to the chain by means of a short rope tied to a ring, which slides along the chain. The chain also serves as a handrail.

A longitudinal barrier pillar about 15 feet thick is left at 150 feet on the incline above the haulage level.

Blasting in diamond-drill holes is with 60-percent, high-velocity gelatin in 1-1/8- by 8-inch cartridges fired with detonating fuse. Larger-diameter cartridges are impracticable in EX down holes drilled in wet ground. When conditions permit, space blasting is employed, using 8-inch wooden spacers. Diamond-drill stopes are blasted once in two to six shifts, or not much oftener than twice per week.

A tamping stick in 3-foot sections is used for charging the holes. These sections are bored for 3 inches at each end along their longitudinal axes and grooved throughout the intervening length. The holes are 5/16 inch in diameter. The sections are threaded on a No. 10 sash cord to form the length required. A blow pipe of 1/2-inch pipe is sectionalized in 3-foot lengths, both ends of which are threaded. The sections are connected by couplings to form the length necessary for cleaning the blast hole.

Boulders are blasted by mud-capping, using 60-percent high-velocity gelatin. The 5- by 16-inch cartridges are cut into 6 to 8 pieces, as required.

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DIAMOND DRILLING

Diamond drilling, which was begun in July 1945, produces 85 percent of the total mine tonnage, or 93 percent of the stoping ore. This method is used in sublevel stoping and is contemplated for the extraction of both longitudinal and transverse pillars. In the near future, the entire mine output, exclusive of ore from development, will be diamond-drilled.

All drilling is by company-owned drills, with payment to miners on a basis of cars of ore produced but with a guaranteed hourly rate. This method was adopted recently instead of payment for the footage of hole drilled, which resulted occasionally in unnecessary holes.

The ground, although generally hard and blocky, has proved to be good drilling, and no holes have been lost, even though drilling water is often lost through fractures in the ore, which probably accounts for high carbon cost. Owing to the nature of the ore, when several rows of holes are drilled the first row blasted usually blocks some of the holes in the adjacent row. Consequently, holes can not be drilled much in advance of actual blasting requirements.

It is easier to train operators for diamond drills for blast-hole drilling than for percussion drills. Men who, among other things, have demonstrated their ability to take good care of their equipment are selected from the mine crew to operate diamond drills. Intelligent workmen, even though inexperienced in mining, can learn in a few shifts how to operate diamond drills for blast-hole drilling. At "Mine B," men who are proficient in operating diamond drills prefer them to percussion drills.

Noise from exhaust air can be reduced by a muffler, but because the exhaust air freezes, most machines are run without mufflers. At "Mine B," an after-cooler is being installed at the compressor, so that with drier compressed air the exhaust should have less tendency to freeze, and the use of mufflers should become practicable.

EQUIPMENT

Seven outfits for diamond-drilling blast holes are on hand, the total cost of which was $22,867.

Details of the inventory of this equipment follow:

	Item	Value (Jan. 1946)
7	Diamond drills @ $775	$5,250
14	2-foot core barrels @ $6	84
2	5-foot core barrels @ $18.50	37
1,200	2-foot drill rods $1.50 per foot	1,800
4	Water swivels @ $20	80
2	Reamers @ $45	90
4	Feed screws @ $25	100

	Item	Value (Jan. 1946)
4	Feed nuts @ $25	100
150	EX diamond bits @ $84	12,600
14	Adapters @ $5.50	77
7	Duplex air-operated circulating pumps, 3" x 2" x 4 @ $100	700
7	Twin-screw columns with clamp and saddle @ $142 ..	994
14	Bushings @ $3.50	49
1	Pneumatic rod puller	100
7	Line oilers with 12-foot oil-resisting hose @ $20	140
7	Miscellaneous spare parts @ $50	350
350	Foot 1-inch air hose @ $0.40	140
350	Foot 1/2-inch water hose for drills @ $0.25	88
350	Foot 1/2-inch water hose for pumps @ $0.25	88
		22,867

Two makes of drill machines are used, which have the following specifications:

Item	Drill A	Drill B
Air motor:		
Type	Rotary	Rotary
Horsepower at 80 pounds air pressure	5	10
Feed:		
Type	Screw	Screw
Run (length, in inches)	24	27
Revolutions per inch of bit advance	100-800	100-1200
Bit speed (range, r.p.m.)	0-1500	0-3300
Weight of drill (pounds)	160	155
Capacity (EX rods, feet)	500	500

The bits are set with diamonds totaling 13 carats of the $6 (May 1946) grade, whose value is $78. The setting charge at the factory is $6 per bit, which makes the maximum total cost of a new bit $84. All bits are noncoring, of the pilot type.

Parcel post with "special handling" has eliminated delays of diamond bits in transit between factory and "Mine B" and has proven the most satisfactory method of shipment. As a result, it has reduced the number of bits that otherwise would be required for stock.

SET-UP

The diamond-drill machines are clamped directly to columns 6 to 10 feet long made from 3-inch extra-heavy pipe, the outside diameter of which is 3.5 inches. All columns are twin-screw, which provide greater rigidity than the single screw. In some instances the column is used as a horizontal bar.

In sublevel stoping an engineer with a transit marks the drill-rings by setting a plug in each wall of the sublevel drift. Ring drilling proceeds by first drilling a horizontal hole, after which succeeding holes are fanned to obtain a 5-foot spacing, or a drilling diagram is used that shows the deflection angle designated for each hole. An inexpensive clinometer of the protractor-head type is used for setting the angles for drilling. A typical diagram for ring drilling is shown in figure 1.

The standard length of drill rods is 2 feet, and the length of core barrel is 2 feet. As the core barrel forms the adapter between the rod and the bit and maintains the alinement of the hole, it is used with noncoring bits. This core barrel has hard facing for a length of about 3 inches on each end to resist wear.

All drilling is by standard EX cast bits with a sintered tungsten matrix, of the pilot or noncoring type, which produce a hole 1.5 inches in diameter.

The air pressure is 100 pounds per square inch at the compressor. Minimum water pressure underground is 110 pounds per square inch.

RESULTS OF DIAMOND DRILLING

At "Mine B," cost records for 28,042 feet of drilling were available. The average bit cost per foot was $0.27 of which $0.22 represented the diamond loss. The most recent bit cost was $0.20 per foot. The life of bits ranged from 15 to 606 feet.

Other operating data are below:

Item	1946 Jan.	1946 Feb.	1946 Mar.
Working days at "Mine B"	26	24	26
Feet of blast holes diamond-drilled	11,505	10,325	8,286
Diamond-drill machine shifts	168	160	140
Feet drilled per diamond drill, machine shift 1/	68.0	2/64.5	2/59.0
Feet drilled, per bit	111	114	109
Feet drilled per 24 hours	442	430	331
Average diamond-drill machine-shifts per 8 hours	3.25	3.35	2.7
Total long tons of ore broken	16,763	17,485	18,000
Long tons of ore broken per diamond-drill machine-shift	100	2/109	2/128
Long tons broken per pound of dynamite in primary blasting	-	-	2.2
Long tons broken per pound of dynamite in secondary blasting (breaking boulders)	-	-	1.9

1/ Diamond-drill crew rigs up drill, clears holes with blow pipe, charges dynamite, and lays the detonating fuse, and connects the circuit for electric firing of the detonating fuse.

2/ On February 11, 1946, the system of pay to miners was changed from the basis of footage drilled to cars of ore produced.

PERCUSSION DRILLING

Comparative data on percussion drilling and diamond drilling could not be obtained, because virtually all stope drilling has been with diamond drills. Percussion drilling was done in development headings and in stope preparation.

All percussion drilling is by means of detachable bits and 1-inch quarter-octagon rods. The powder used in development headings is 60 percent semigelatin dynamite detonated by delay-action electric caps. Considerable difficulty in removing sludge and cuttings in ore has been experienced with hand-held sinker drills when drilling down holes more than 5 feet deep.

Automatic, rotating stoper drills are used in all raises and sublevel drifts. In order to support the tailpiece while drilling a drift heading, a 2-inch plank is blocked across the sublevel drift at 7 feet from the breast. With this set-up, a stoper can drill all the holes in the round. Some miners can operate two stopers in the heading simultaneously.

The purchase price of a mounted drifter drill with accessories for use in sublevel stoping is below:

1	Drifter with automatic feed	$540
1	Twin-screw column, complete with arm and clamp	142
3	Sets 1-inch quarter octagon drill rods (10 feet max. length) ..	180
500	Drill bits @ $0.30	150
50	Feet 1/2-inch water hose @ $0.25 per foot	12
50	Feet 1-inch air hose @ $0.40 per foot	20
1	Line oiler with oil-resisting hose	20
		$1,064

This equipment is exclusive of that required in the drill-sharpening shop.

ADVANTAGES AND DISADVANTAGES OF DIAMOND DRILLING BLAST HOLES AT "MINE B"

The advantages of diamond-drilling blast holes at "Mine B" are:

1. Greater safety to the miner because he always drills from a set-up close to the back, which is thus under constant observation.

2. Greater safety to the scraper operator because tail blocks for the scraper are anchored to the wall of the bench, which obviates the hazard of placing the blocks at the foot of the slope of the bench in the open stope.

3. Additional ore can be recovered safely with diamond drills, not only from pillars but also from open stopes.

4. In the bench method of sublevel stoping, at least one-half the sublevel development footage is eliminated.

5. Primary blasting is reduced from once each shift to once in two to six shifts.

6. Dust from drilling is virtually eliminated.

7. Operators can be trained more easily for diamond drills than for percussion drills.

No serious disadvantages have been found in diamond-drilling blast holes at Eastern Magnetite "Mine B."

One problem in diamond drilling that arose from the comparatively small number of diamond drills in service was how to carry extra drill operators to substitute for absentees, as it was difficult to find suitable work for them when not engaged in drilling. The greater bit cost per foot of diamond drilling was more than compensated by greater safety to the workman, by greater efficiency in blasting, by less development, and by other advantages.

CONCLUSIONS

A difficult mining problem at "Mine B" has been solved by diamond-drilling blast holes, which has made possible the safe extraction of the ore by sublevel open stoping.